



WinVIBRO2 USER'S GUIDE

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WinVIBRO2 User's Guide

by

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Abstract

This document is a guide for using the Windows 95/98 version of the computer code WinVIBRO2, an implementation of theoretical models presented in the DREA Reports "Computational Evaluation of Decoupling and Damping Materials, Phase I and III". This code allows the vibroacoustic response of a baffled, rectangular plate immersed in a heavy fluid on one side to be calculated, either with or without a noise reduction coating. Seven numerical algorithms are implemented in the code : (1) the case of a base plate alone, the case of a base plate covered by a decoupling coating (3 models are available : (2) locally reacting model, (3) 3D model and (4) simplified 3D model), (5) the case of a sandwich plate, (6) the case of a sandwich plate covered by a decoupling coating and (7) the case of a base plate partially covered by a constrained viscoelastic treatment. The input parameters required for the code are described, the method to use the code is presented as well as the vibroacoustic indicators calculated by WinVIBRO2. Algorithms used for the main types of numerical methods available in the program are also listed.

Résumé

Ce document est un guide d'utilisation pour la version Windows 95/98 du programme informatique WinVIBRO2, qui est basé sur une étude théorique présentée dans les rapports "Computational Evaluation of Decoupling and Damping Materials, Phase I et III". Ce programme permet de calculer la réponse vibroacoustique d'une plaque bafflée, rectangulaire immergée dans un fluide lourd sur une face, avec ou sans traitement amortissant. Sept algorithmes numériques sont implantés dans le programme : (1) le cas d'une plaque de base seule, le cas d'une plaque couverte par un matériau de masquage (trois modèles sont disponibles : (2) modèle à réaction localisée, (3) modèle tridimensionnel et (4) modèle tridimensionnel simplifié), (5) le cas d'une plaque sandwich, (6) le cas d'une plaque sandwich recouverte par un matériau de masquage et (7) le cas d'une plaque couverte par un traitement viscoélastique contraint partiel. Les paramètres d'entrée requis pour l'utilisation du programme sont décrits, la manière d'utiliser le code est présenté ainsi que les indicateurs vibroacoustiques calculés par WinVIBRO2. Les principaux algorithmes utilisés dans le code sont également présentés.

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WinVIBRO2 : User's Guide

1 Introduction

The information needed to use the version 2 of the code WinVIBRO (WinVIBRO2.exe) is presented in this document. This code is based on the theoretical study presented in the DREA report CR/96/427 "*Computational evaluation of decoupling and damping materials – Phase I*" and in the report "*Computational evaluation of decoupling and damping materials – Phase II*". In this document the main features and capabilities of the code are presented :

- Input/output parameters
- How to run the program
- How to account for the frequency dependence of the viscoelastic materials
- How to adjust important input parameters, such as the *modal expansion order* and of the parameters for the numerical calculation of the *radiation impedance*
- The frequency interpolation algorithm for the radiation impedance matrix is presented ;

2 Presentation of the code

WinVIBRO2 is software dedicated to the calculation of the vibro-acoustic response of a baffled, simply supported plate, immersed in a heavy fluid on one side, and including surface decoupling / damping treatments. The following sections briefly present the main features of the code in terms of :

1. The excitations of the structure
2. The characteristics of the structure (geometric and material properties)
3. The characteristics of the fluid

4. The output parameters.

2.1 *Excitation*

Mechanical and acoustic excitation of the plate are possible. The acoustic excitation is a plane wave impinging the plate on the emitting side (figure 1), with an arbitrary angle of incidence. The mechanical excitation is a transverse point force at an arbitrary location on the plate surface.

2.2 *Characteristics of the structure*

The plate is a rectangular, baffled plate with simply supported boundary condition on the four edges. Four different types of plates are considered in the code. The theoretical models used to describe the behaviour of the various plates are in the DREA report CR/96/427 and in the DREA report "*Computational evaluation of decoupling and damping materials – Phase IIP*".

1. A base plate with no treatment (chapter 2 of the DREA report CR/96/427).
2. A base plate covered by a decoupling layer (locally reacting model, chapter 3 of the DREA report CR/96/427).
3. A base plate covered by a decoupling layer (3D model, DREA report "*Computational evaluation of decoupling and damping materials – Phase IIP*", chapter 2).
4. A base plate covered by a decoupling layer (simplified 3D model with only compressional waves, DREA report "*Computational evaluation of decoupling and damping materials – Phase IIP*", chapter 2).
5. A sandwich plate (base plate + viscoelastic layer + constraining layer, chapter 5 of the DREA report CR/96/427).
6. A sandwich plate covered by a decoupling layer (chapter 7 of the DREA report CR/96/427).
7. A simply supported base plate partially covered by a constrained damping treatment (viscoelastic layer + constraining layer, DREA report "*Computational evaluation of decoupling and damping materials – Phase IIP*", chapter 5).

2.3 Characteristics of the fluid

The fluid where the acoustic radiation takes place has an arbitrary density (can be either a light fluid or a heavy fluid). The fluid on the other side of the plate is assumed to be a light fluid (creates no fluid loading of the plate).

2.4 Vibro-acoustic indicators

VIBRO calculates the following vibro-acoustic indicators (see DREA report CR/96/427 and DREA report "*Computational evaluation of decoupling and damping materials – Phase III*") :

- The mean square velocity of the base plate.
- The mean square velocity of the outer surface of the decoupling layer.
- The ratio of the mean square velocity of the base plate to the mean square velocity of the outer surface of the decoupling layer.
- The radiated sound power in the heavy fluid.
- The radiation efficiency of the plate (in the heavy fluid).
- The transmission loss (only if the excitation is a plane wave).
- The near field acoustic power
- The acceleration at a given point on the base plate
- The acceleration at a given point on the coating surface
- The acceleration at the driving point (only if the excitation is a point force).
- The vibrational shape of the base plate.

- The vibrational shape of the outer surface of the decoupling layer.
- The global loss factor of the plate (pertaining to damping materials).
- The insertion loss in 1/3 octave band.

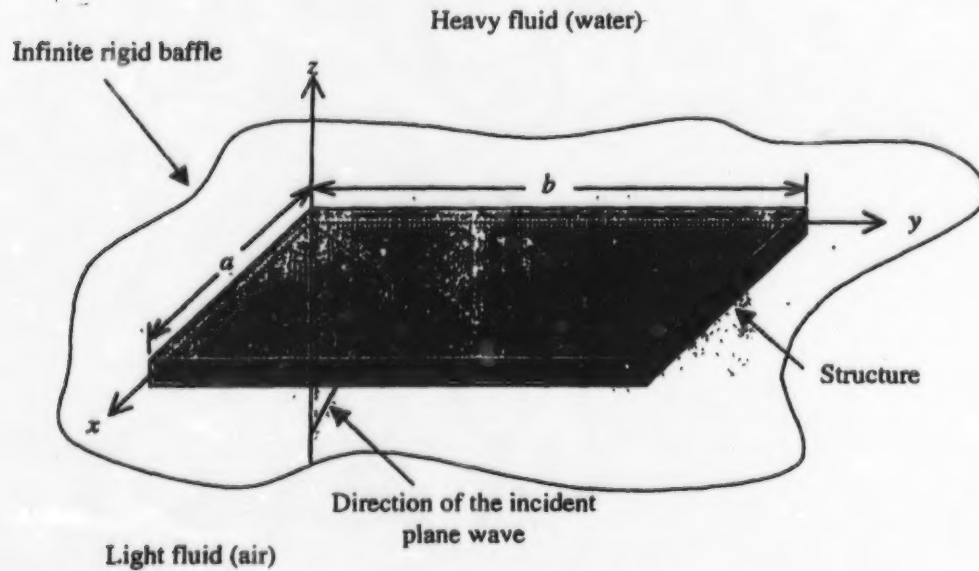


Figure 1. Schematics of the baffled plate with the an incident plane wave excitation.

3 How to use the version 2 of WinVIBRO

The following section explains how to use the version 2 of WinVIBRO (for Windows 95 / 98).

3.1 Initialisation of the input file

When you click on the shortcut icon of WinVIBRO2 : , the main window appears (see figure 2). You can either open an already existing input data file (*.vib) or create a new one. To create a new input data file you can use the menu "File" and the items "New" or "Open" or the icons  (new) and  (open). **All input files should always have the extension ".vib".**

If you choose to create a new input file you have to fill the WinVIBRO2 input file. To do that you have to successively open four dialog boxes and fill them ; choose the menu "Input", then the items "Options of calculation" (or click on the icon ) , "Characteristics of the layers" (icon ) , "Excitation of the plate" (icon ) , and "Output parameters (icon )" :

1. When you click on the item "Options of calculation" (or icon ) , the menu of the figure 3 appears. You just have to fill the dialog box.
2. When you click on the item "Characteristics of the layers" (or icon ) , the menu of the figure 4 appears. First choose the type of system you want to simulate, there are 7 possibilities :
 - Base plate alone
 - Base plate + decoupling layer (locally reacting model)
 - Base plate + decoupling layer (3D model with only compressional wave)
 - Base plate + decoupling layer (3D model)
 - Sandwich plate

- Sandwich plate + decoupling layer (locally reacting model)
- Partial coverage with constrained damping material

Then, you can click on the following buttons to define the characteristics of each layer of the system :

- a) Button "Base plate" (figure 5).
 - b) Button "Decoupling layer" (figure 6).
 - c) Button "Viscoelastic layer" (figure 7).
 - d) Button "Constraining layer" (figure 8).
1. By clicking on the item "Excitation of the plate" (or icon ) , the menu of the figure 9 appears.
 2. By clicking on the item "Output parameters" (or icon ) , the menu of the figure 10 appears.

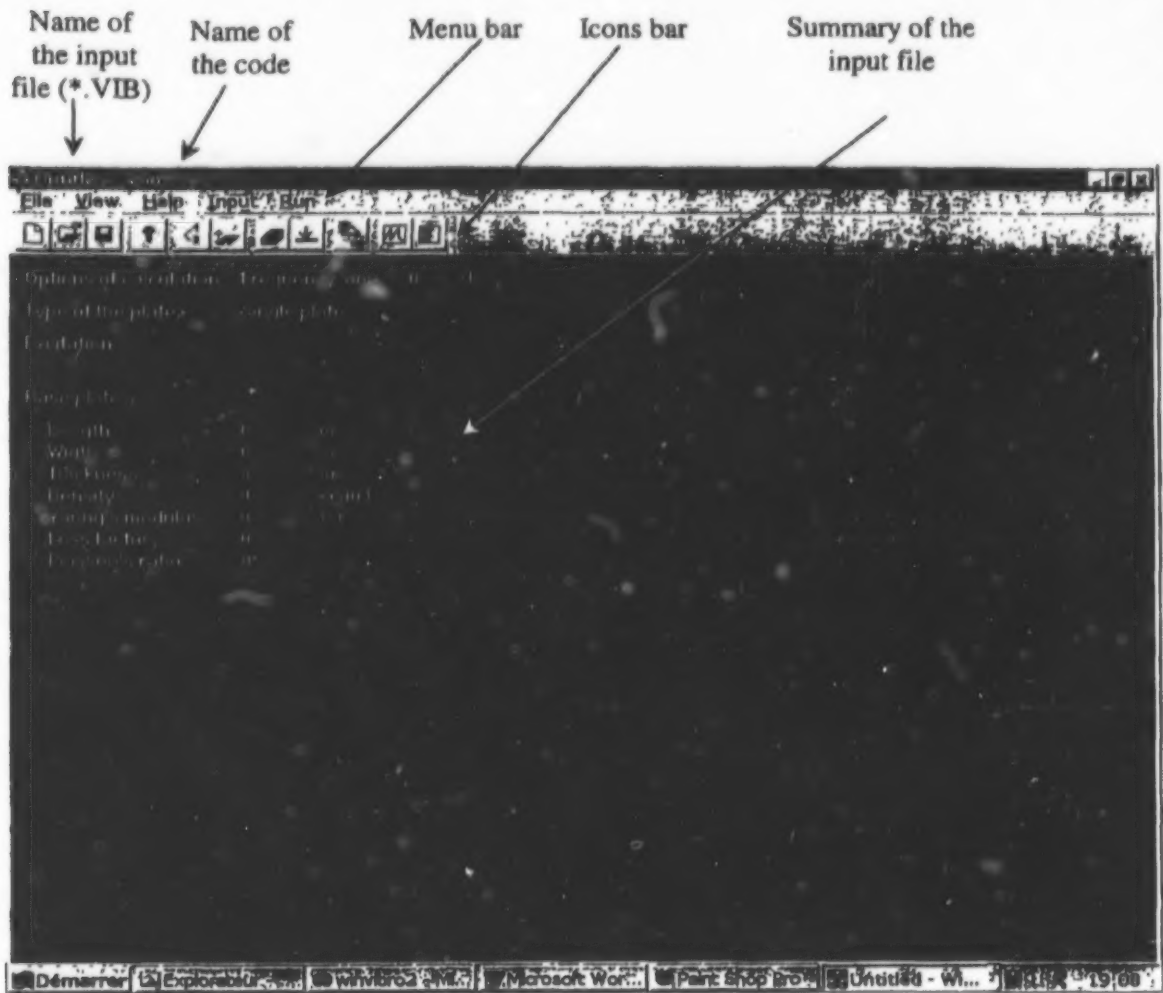
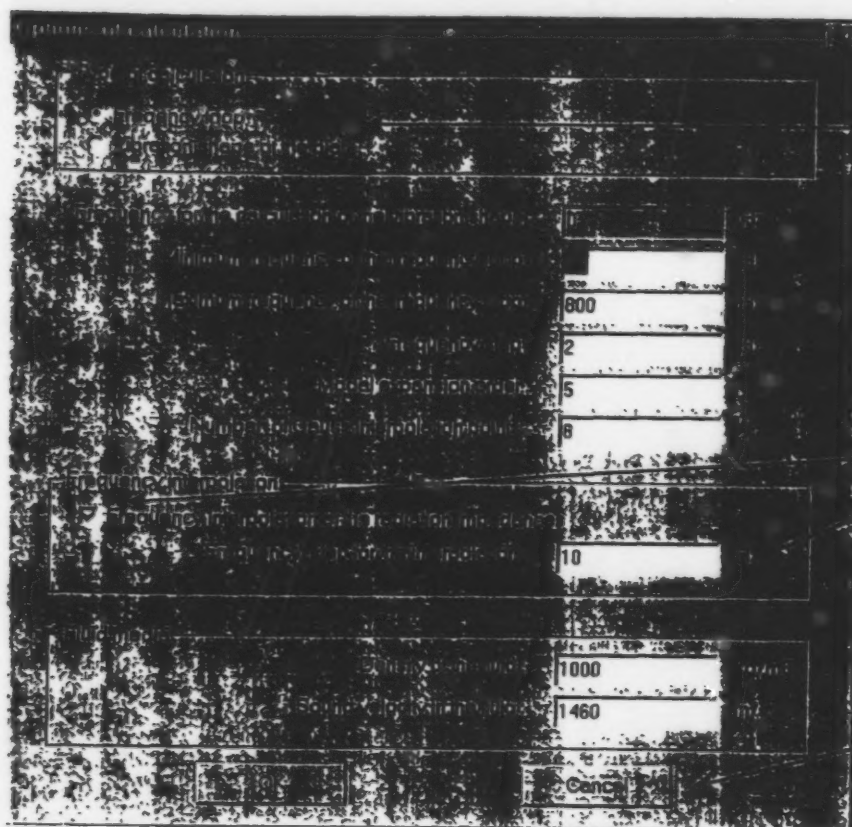


Figure 2. Initial window of WinVIBRO2.



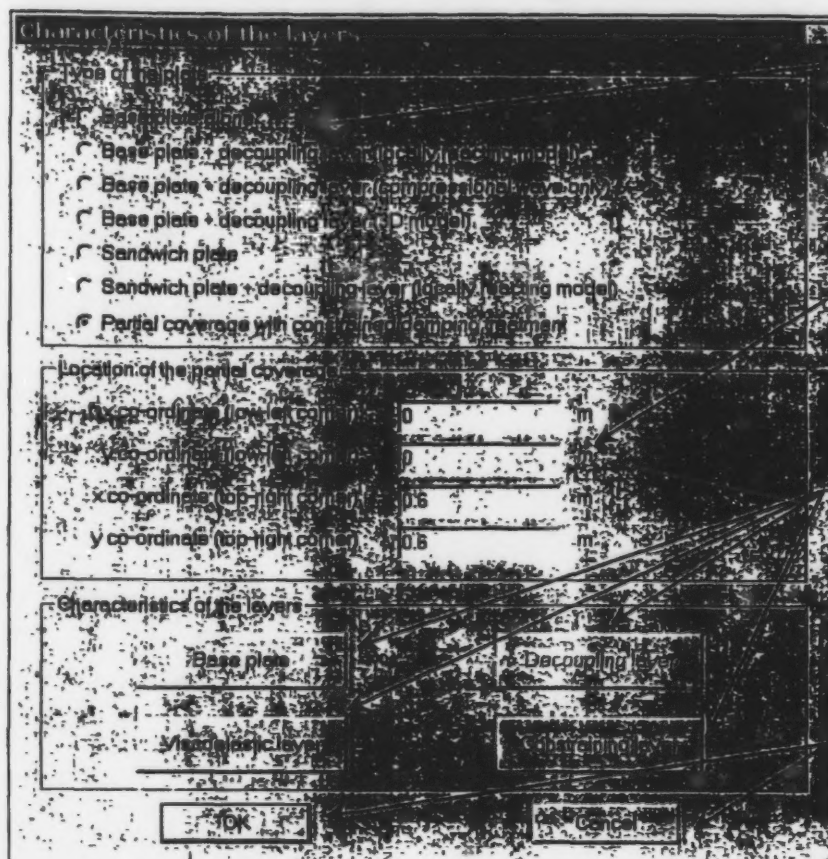
1. Choose one option

2. Fill the blank boxes.

If you use the frequency interpolation click here. Then, choose the frequency step.

3. Click OK to save or cancel to abort.

Figure 3. Menu : Options of calculation.



1. Choose one option

If partial coverage with constrained damping is chosen, the surface of the coverage has to be defined (the origin of the reper is in the low-left corner of the plate see section 4)

2. Click on these buttons to specify the characteristics of each layer.

3. Click OK to save or cancel to abort.

Figure 4. Menu : Characteristics of the layers.

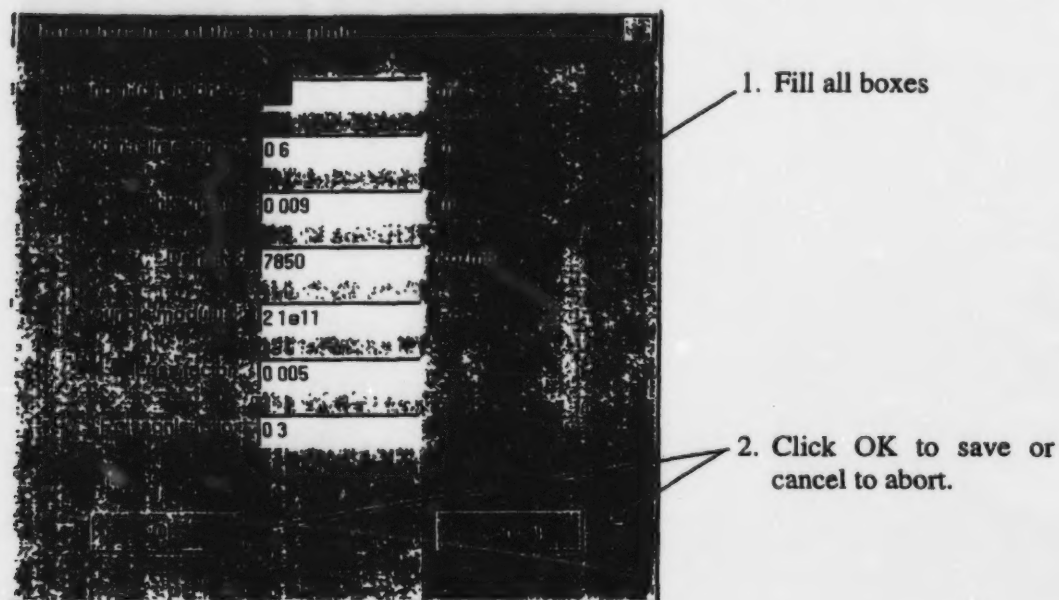


Figure 5. Menu : Characteristics of the base plate.

If decoupling layer is characterised by mechanical properties or if it is defined by acoustic properties (speed velocity)

Characteristics of the decoupling layer

☐ Mechanical properties

Young's modulus independent of the frequency:

Poisson's ratio independent of the frequency:

☐ Acoustic properties

Sound speed:

Wave speed:

☐ Imaginary part

Real part:

Imaginary part:

OK Cancel

1. Fill all boxes.

Chose one option, then, fill the corresponding boxes.

Use Browse button to choose the file

2. Click OK to save or cancel to abort.

Figure 6. Menu : Characteristics of the decoupling layer.

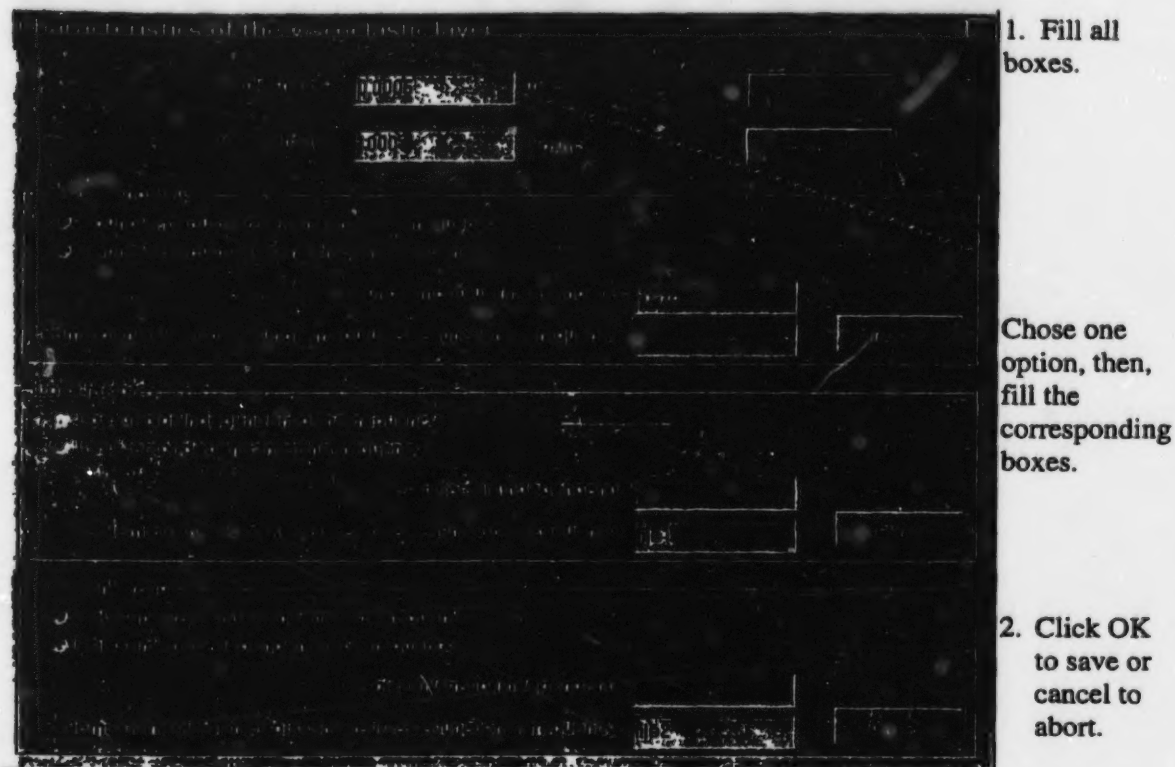


Figure 7. Menu : Characteristics of the decoupling layer.

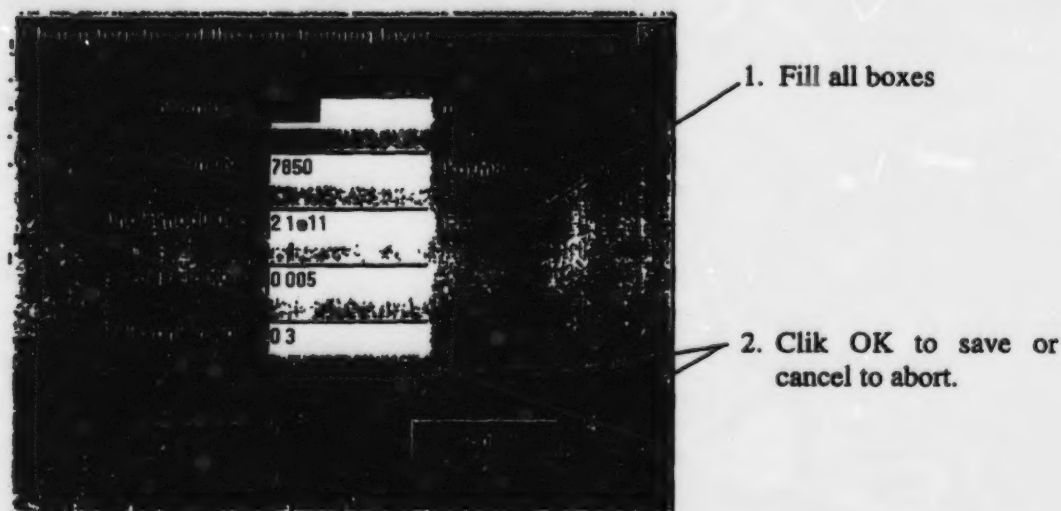
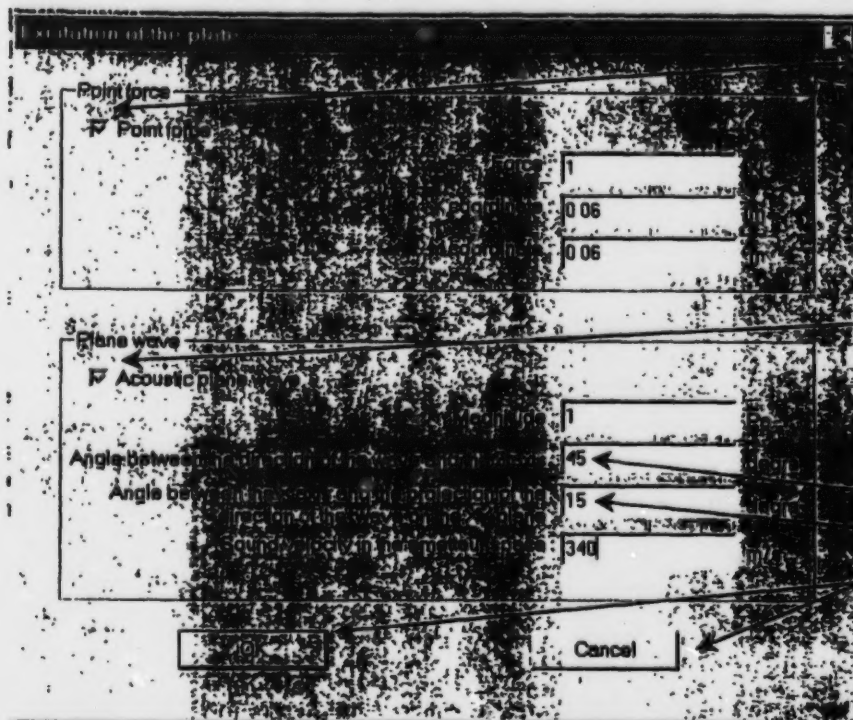
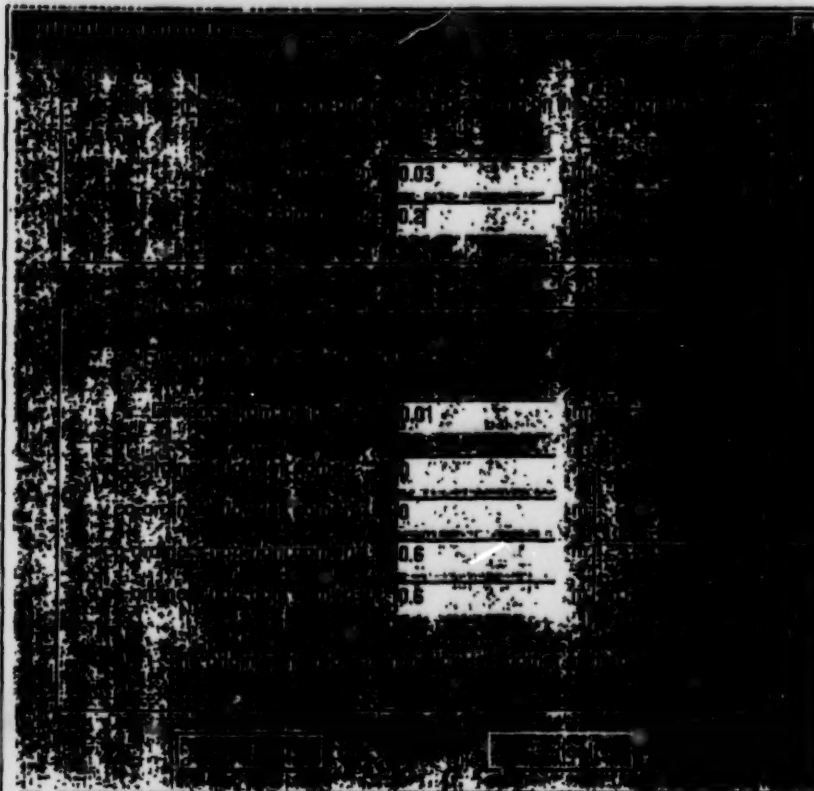


Figure 8. Menu : Characteristics of the decoupling layer.



1. Click here to create a point force, then, fill the corresponding boxes.
2. Click here to create a plane wave excitation, then, fill the corresponding boxes.
3. Click OK to save or cancel to abort.

Figure 9. Menu : Excitation of the plate (you can create a point force and a plane wave excitation simultaneously).



Co-ordinates of the point on the base plate to calculate the acceleration

Distance between the plate and the calculation plane (only positive value)

Co-ordinates of the calculation plane (negative or positive values are acceptable)

Figure 10. Menu : output parameters.

3.2 Run the program

To run the program, save the input data file first if it is a new one, then select the menu "Run", item "Run program" or the icon . The code runs in background but it can be stopped at any time by clicking the button "Cancel". At the end of the run the main window is enlarged.

3.3 Result files

When the calculation is completed the menu of figure 11 appears. It gives the names of the result files created by the code and the directory where they are saved. The code creates the result files in the directory where the input file is saved. Click OK to leave this menu. The names of the result files are automatically chosen by the code, by using the name of the input data file (plate0, in the examples presented here) plus the following extensions :

.mv1	Mean square velocity of the base plate.
.mv2	Mean square velocity of the outer surface of the decoupling layer.
.spw	Radiated sound power.
.ref	Radiation efficiency.
.rto	Mean square velocity ratio.
.ipw	Input power
.acc	Acceleration at a defined point on the base plate
.acd	Acceleration at a defined point on the coating surface
.acx	Acceleration at the driving point (only for point force excitation)
.nfp	Near field acoustic power
.trl	Transmission loss (only for plane wave excitation)
.sh1	Vibration shape of the base plate.
.sh2	Vibration shape of the outer surface of the decoupling layer.
.los	Global loss factor (only for damping treatment).
,	Insertion loss in 1/3 octave band (the name of the insertion loss is chosen by the user).

You can check the name of the result files at any time by selecting the menu "Run" and the item "Name of the result files". In this case the menu of the figure 11 appears even if the calculation is not completed and the files are not created.

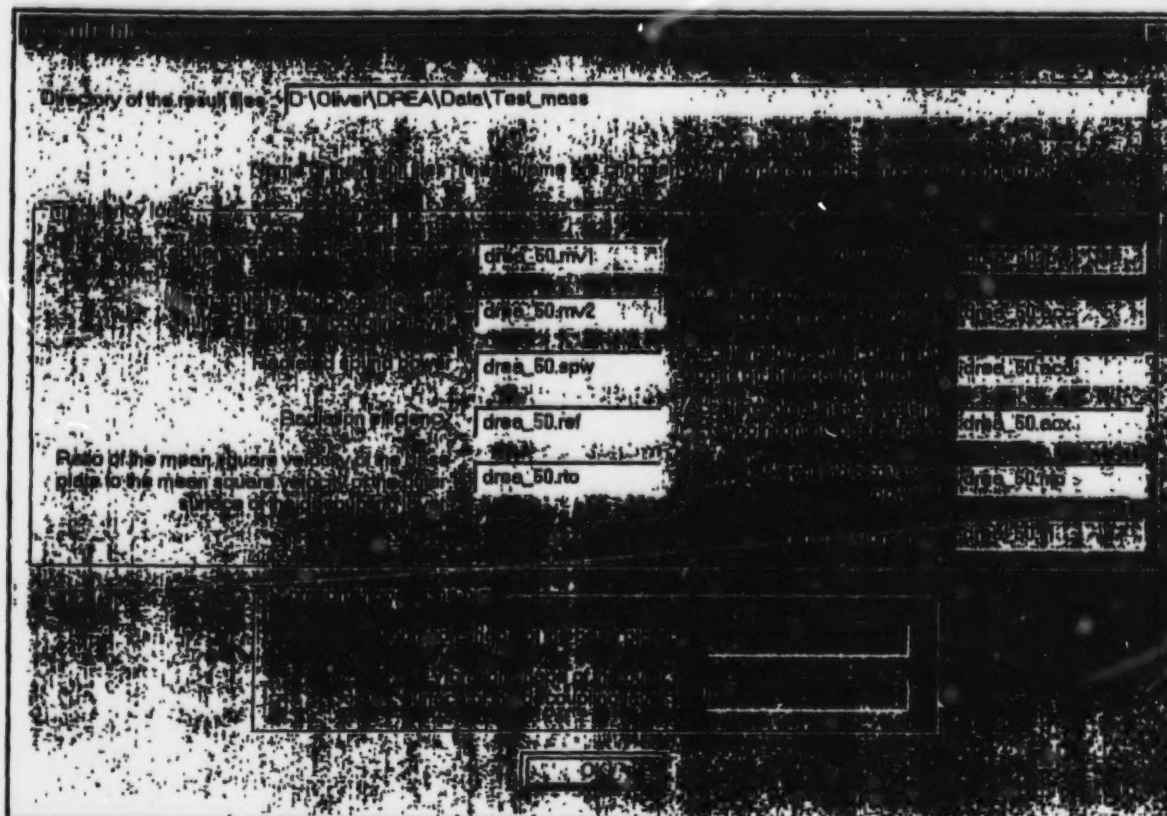


Figure 11. At the end of the run this box is displayed to give the name of the result files and the directory where they are saved.

3.4 Global loss factor

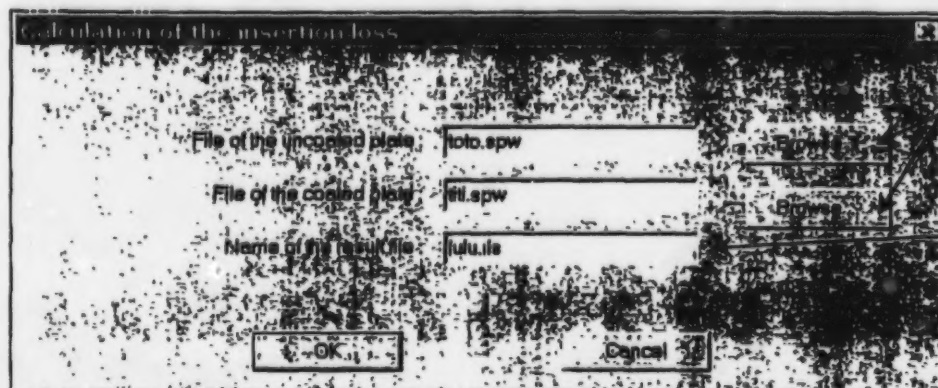
To calculate the global loss factor of a plate covered by a damping treatment (free- or constrained-layer damping) you have to choose the menu "Run" and the item "Global loss factor". The program will calculate the global loss factor of the 2- or 3-layered plate defined in the input data file. This calculation is not allowed for a single plate or a plate covered by a decoupling layer. If the system defined in the input data file is a sandwich plate covered by a decoupling layer, the code will calculate the global loss factor of the sandwich plate and ignore the decoupling layer. At the end of the calculation a message box displays the name of the result file. If a free-viscoelastic treatment is considered (the constraining layer thickness should be null) the global loss factor is independent of the frequency, thus, there is only one value in the result file. If a constrained-viscoelastic treatment is considered the result file has two columns. The first column is the frequency (Hz) and the second column is the global loss factor. The result file is created in the directory where the input file is saved.

3.5 Insertion loss in 1/3 octave band

The calculation of the insertion loss in 1/3 octave band is a complete independent option of the code. You have select the menu "Run" and the item "Insertion loss" (the menu of the figure 12 appears). It calculates the 1/3 octave band response of the chosen files and take the ratio of the uncoated result to the coated result :

$$IL = 10 \log_{10} \left(\frac{W_{uncoated}}{W_{coated}} \right).$$

The same frequency range and the same frequency step should be used for the calculation of the sound power with and without the treatment.



Use Browse button to choose files

Name of the file that contains the calculation of the insertion loss in 1/3 octave band.

Figure 12. Menu : Calculation of the insertion loss.

3.6 Display option

WinVIBRO2 allows to plot curves at screen. When clicking on the icon  the menu of figure 13 appears. The user has to choose an ascii files that contains two columns (typically x , y) and the code will plot this file when the user strike the "plot" button. WinVIBRO2 can plot at maximum 10 curves. The files to be plotted does not need to be created by WinVIBRO2.

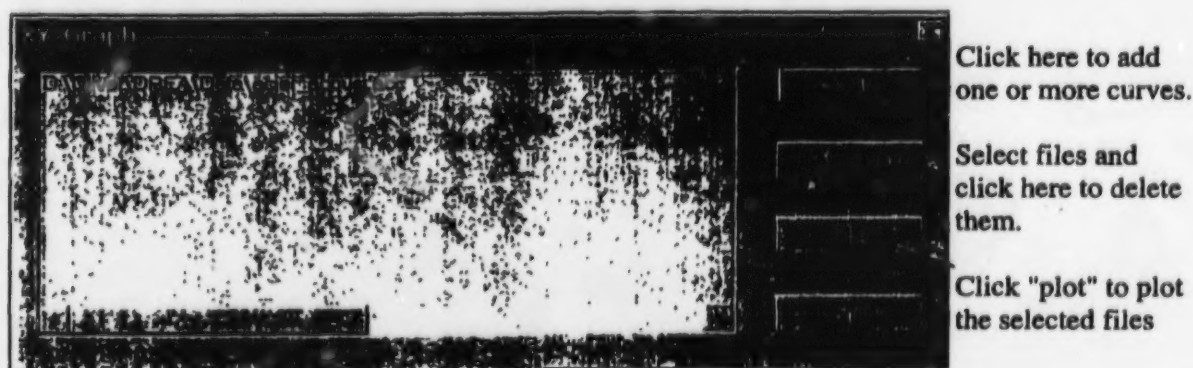


Figure 13. Menu to choose files to be plotted.

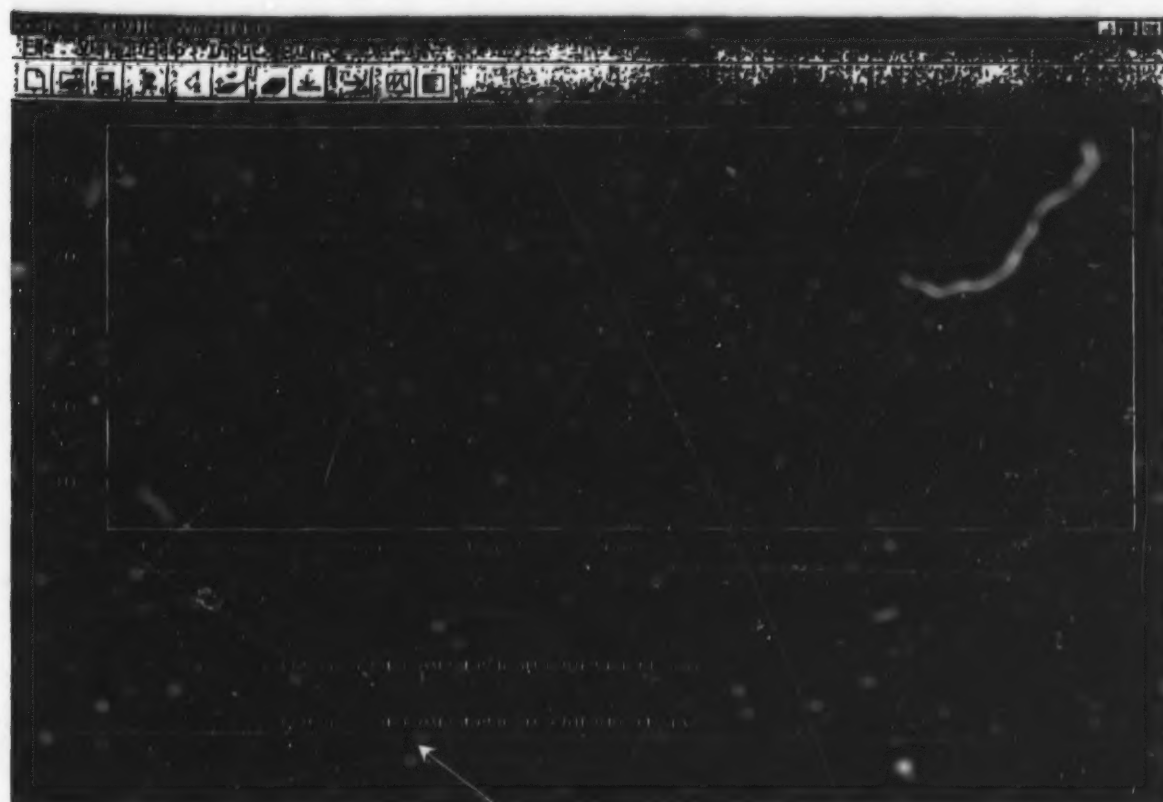


Figure 14. Example of graphic display. Path of the plotted files (10 files maximum).

4 Mapping plane and partial coverage area

This section explain how to define coordinates of the mapping plane used in the evaluation of the near field acoustic power and coordinates of the partial damping coverage. Figure 15 presents the coordinates system of the surface used to calculate the near field acoustic power. The location and the area of this surface is user defined. Negative value are possible for the four coordinates $l_{\min}^x$, $l_{\max}^x$, $l_{\min}^y$, $l_{\max}^y$ and the surface can be either smaller or larger than the plate. The coordinates of the surface are initialized in the dialog box "Output parameters"(see figure 10).

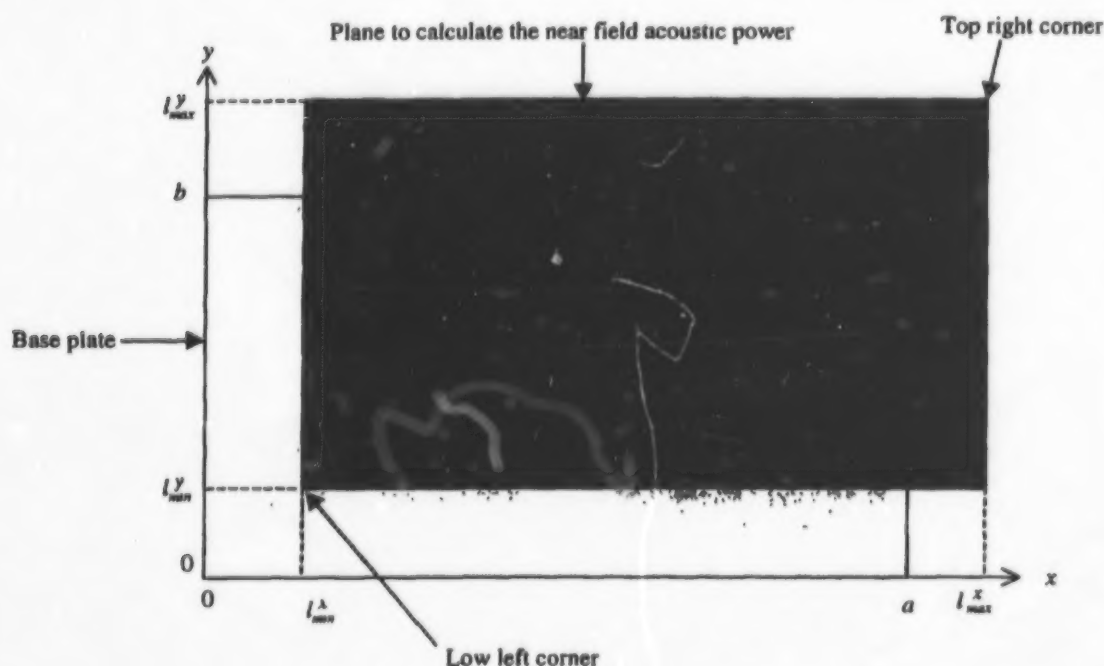


Figure 15. Coordinate system used for the mapping plane of the near field acoustic power.

Figure 16 presents the coordinate system used to defined the location of the partial coverage on the base plate. The surface of the coverage is at maximum equal to the plate surface. The coordinates of the partial coverage are initialized in the dialog box "Characteristics of the layers" (see figure 4).

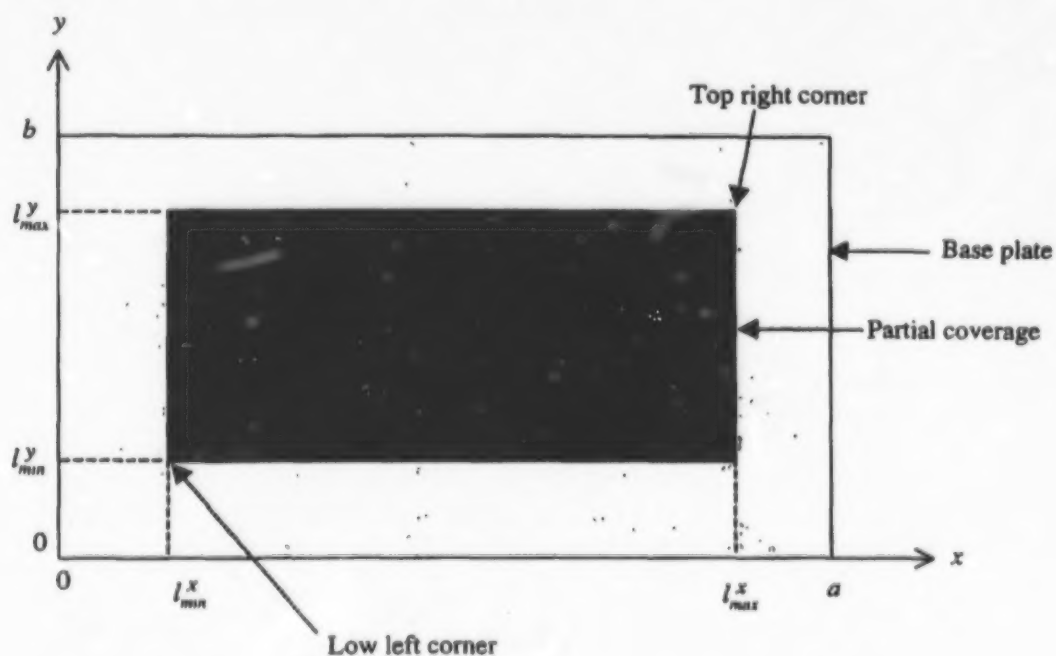


Figure 16. Coordinate system used for the location of the partial coverage on the base plate.

5 Frequency dependence of the decoupling layer and the viscoelastic layer

The numerical code can take into account frequency-dependent properties of the decoupling layer and of the damping layer. This option is available for the Young's modulus (or bulk modulus), the loss factor (decoupling layer and damping layer) and the poisson's ratio of the damping layer. **In order to use this option, a file that contains the values (Young's modulus or loss factor) as a function of the frequency, have to be created before running the program.** Two examples of such files are given below :

example of file of the Young's modulus (or plate modulus)

Frequency (Hz)	50 100 500 1000	6×10^7 6×10^7 7×10^7 7.5×10^7	Young's modulus or bulk modulus (Pa)
----------------	---	---	--------------------------------------

example of file of the loss factor

Frequency (Hz)	50 100 500 1000 1500	0.5 0.6 0.7 0.6 0.5	loss factor
----------------	---	--	-------------

Once these files are created the user has to specify the name of these files in the appropriate dialog boxes, "Characteristics of the decoupling layer" (figure 6), "Characteristics of the viscoelastic layer" (figure 7).

6 Result files

The result (or output) files created by VIBRO are :

- The mean square velocity of the base plate (*.mv1).
- The mean square velocity of the outer surface of the decoupling layer (*.mv2).
- The ratio of the mean square velocity of the base plate to the mean square velocity of the outer surface of the decoupling layer (*.rto).
- The radiated sound power in the heavy fluid (*.spw).
- The radiation efficiency of the plate/fluid system (*.ref).
- The input power (*.ipw).
- The acceleration at a user defined point on the base plate (*.acc).
- The acceleration at a user defined point on the coating surface (*.acd).
- The acceleration at the driving point (only if the excitation is point force) (*.acx).
- The near field acoustic power (*.nfp).
- The transmission loss (only if the excitation is a plane wave) (*.trl).
- The vibration shape of the base plate at a given frequency (*.sh1).
- The vibration shape of the outer surface of the decoupling layer at a given frequency (*.sh2).
- The global loss factor of an infinite plate (only for damping treatments) (*.los).
- The insertion loss in 1/3 octave band (user's defined name).

When a vibroacoustic indicator is calculated as a function of the frequency (mean square velocity, mean square velocity ratio, radiation efficiency, radiated power, insertion loss...) all the output files have the same, 2-column format : the first column is the frequency (Hz) and the second column is the corresponding value of the vibroacoustic indicator (in dB). A reference value is used for the dB conversion only in the case of the radiated sound power:

$$L_W = 10 \log_{10} \left(\frac{W}{10^{-12}} \right)$$

For the other vibroacoustic indicators the dB conversion is simply defined by : $L_X = 10 \log_{10}(X)$, where X is the value of the indicator.

When the vibration shape of the plate is calculated at a given frequency, the code generates the transverse displacement of the plate at 2500 points (50×50) evenly distributed on the plate. The result file has the following format (only the beginning of the file is shown) :

The diagram illustrates the format of the result file. It consists of three vertical columns enclosed in a single rectangular frame. The first column is labeled 'x coordinates (m)' with an arrow pointing to it. The second column is labeled 'y coordinates (m)' with an arrow pointing to it. The third column is labeled 'displacement of the structure at the point (x,y) (m)' with an arrow pointing to it. The data in the columns is as follows:

0	0	0
0.1	0	0
0.2	0	0
0	0.1	0
0.1	0.1	1×10^{-7}
:	:	

7 Important parameters

Two input parameters are important in terms of the accuracy of the numerical results ; these are the *modal expansion order* and the number of *Gauss interpolation points*. The way of adjusting these input parameters is investigated in this section.

7.1 Modal expansion order

The modal expansion order is defined as the maximum integer N in the summation over the in-vacuo modes of the structure, of the normal displacement $w(x,y)$:

$$w(x,y) = \sum_{m=1}^N \sum_{n=1}^N a_{mn} \sin\left(m\pi \frac{x}{a}\right) \sin\left(n\pi \frac{y}{b}\right) \quad (1)$$

Increasing N increases the number of sine functions used to reconstruct the transverse displacement of the system, and thus improves the accuracy of the results. Also, higher values of N will allow predictions in higher frequency.

Figures 17 and 18 show the mean square velocity and the radiated sound power of a bare steel plate, for four different values of N . It is seen that increasing N increases the accuracy of the results in higher frequency. Obviously, a given value of N will allow proper reconstruction of mode orders up to N in each of the x - and y -directions. The associated frequency limit depends on the modal density of the structure ; in practice, it is always possible to verify that convergence has been reached by increasing N and verifying that the result is unchanged.

The characteristics of the plate used for the simulations of Figures 12 and 13 are listed below :

Table 1, characteristics of the steel plate used for the numerical results of Figs 12 and 13.

length (m)	width (m)	thickness (mm)	density (kg/m ³)	Young's modulus (Pa)	loss factor	Poisson ratio
0.6	0.6	9	7850	2.1×10^{11}	0.005	0.3

The excitation is a point force applied at $x = y = 0.06$ m from a corner of the plate.

The fluid is water (density $\rho_0 = 1000$ kg/m³ , sound speed $c_0 = 1460$ m/s).

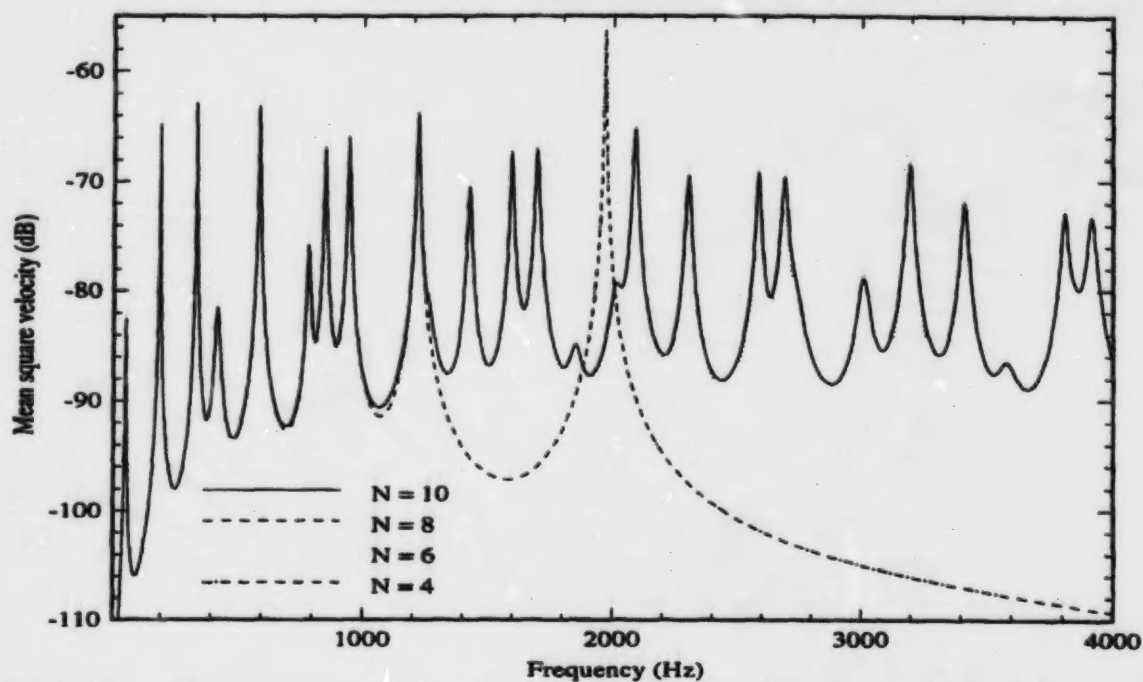


Figure 17. Mean square velocity of a steel plate for four different values of the modal expansion order N .

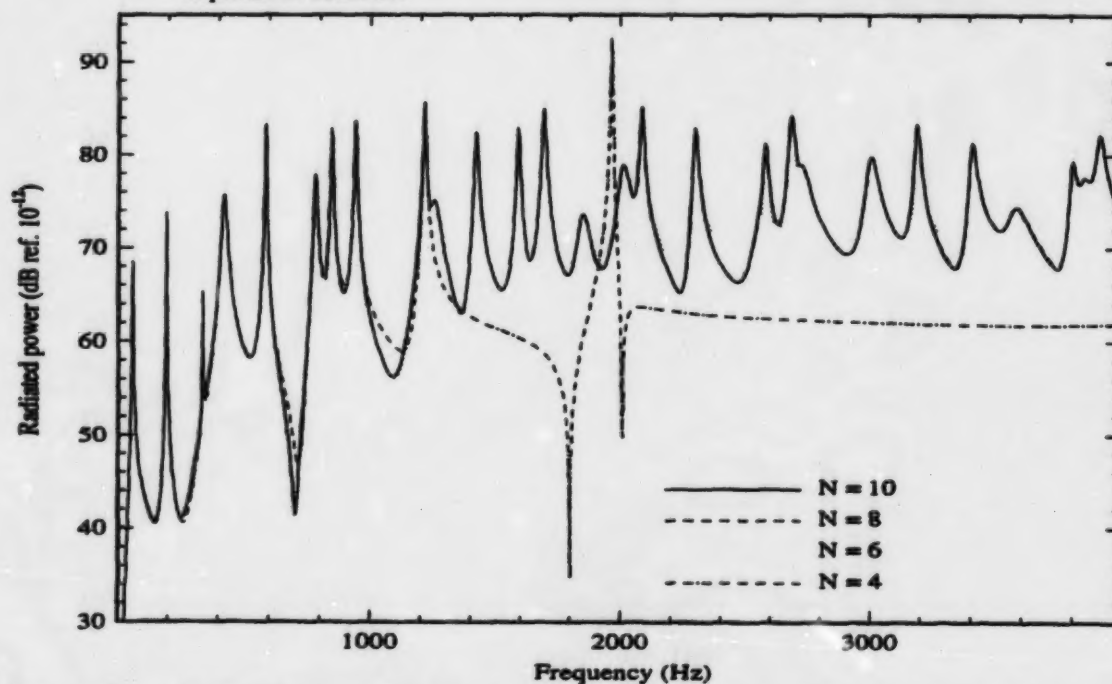


Figure 18. Radiated sound power of a steel plate for four different values of the modal expansion order N .

7.2 Number of Gauss interpolation points

A numerical method (Gauss method) is used to calculate the radiation impedance matrix (appendix 2 of the DREA report CR/96/427) and the near field acoustic power ("Computational evaluation of decoupling and damping materials - Phase III", section 2.4.2). Since these terms are frequency dependent they must be calculated for each frequency.

Each term of the radiation impedance matrix Z_{mnpq} is defined by :

$$Z_{mnpq} = j\rho_0\omega \int_S \int_S \int_S \int_S w_{pq}(x, y) G(x, y, 0, x', y', 0) w_{mn}(x', y') dx' dy' dx dy \quad (2)$$

where G is the Green's function and w_{mn} and w_{pq} are the in-vacuo eigenfunctions of the plate. Using the method presented in appendix 2 of the DREA report CR/96/427, the quadruple integral can be reduced into a double integral :

$$Z_{mnpq} = j\rho_0\omega \frac{ab^2}{4\pi} \int_{-1}^1 \int_{-1}^1 f(u, u') du du' \quad (3)$$

where $f(u, u')$ is detailed in appendix 2 of the DREA report CR/96/427.

To calculate the double integral in Eq. (3), a Gauss numerical method is used. This method allows to write :

$$Z_{mnpq} = j\rho_0\omega \frac{ab^2}{4\pi} \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} p_i p_j f(u_i, u'_j) \quad (4)$$

where p_i and p_j are the weights associated to the discrete point u_i and u_j respectively (these points are in the interval $]-1, 1[$). The number of Gauss interpolation points N_g is a very important parameter because it has a direct effect on the accuracy of the numerical value for the integral. Larger values of N_g lead to more accurate results. However, the computation time increases rapidly with N_g , so that a compromise has to be found.

The Near field acoustic power is defined by :

$$\int_{S_i} |I_z(M)| dS_i = \frac{1}{2} \rho_0 \omega^3 \operatorname{Re} \left[\int_{S_i} \int_{S_Q} G(M, Q) u_z(Q) dS_Q \int_{S_Q} \left(\frac{G(M, Q')}{\partial z} \right)^* (u_z(Q'))^* dS_Q' \right] \quad (5)$$

Using appropriate change of variable to performed all integrals in the interval $]-1, 1[$, the Gauss numerical method leads to the following relation to calculate the near field acoustic power :

$$\iint_{S_i} I_z(M) dS_i = \frac{1}{2} \rho_0 \omega^3 R e \left[\sum_{m,n}^N p_i p_j \left| j \sum_{p,q}^{N-1} p_p p_q G(x_m, y_n, x_p, y_q) u_Z(x_p, y_q) \right. \right. \\ \left. \left. \sum_{r,s}^{N-1} p_r p_s \left(\frac{G(x_m, y_n, x_r, y_s)}{\partial z} \right)^* (u_Z(x_r, y_s))^* \right| \right] \quad (6)$$

The Green's function and the complex conjugate of the derivative of the Green's function are given by :

$$\begin{cases} G(x_m, y_n, x_p, y_q) = \frac{e^{jk_0 R_{mnpq}}}{2\pi R_{mnpq}} \\ \left(\frac{\partial G(x_m, y_n, x_r, y_s)}{\partial z} \right)^* = -\frac{ze^{jk_0 R_{mnrs}}}{2\pi (R_{mnrs})^3} (1 - jk_0 R_{mnrs}) \end{cases} \quad (7)$$

where $R_{mnpq} = ((x_m - x_p)^2 + (y_n - y_q)^2 + z^2)^{1/2}$ and

$R_{mnrs} = ((x_m - x_r)^2 + (y_n - y_s)^2 + z^2)^{1/2}$, $p_m, p_n, p_p, p_q, p_r, p_s$, are weights respectively associated to discrete points $x_m, y_n, x_p, y_q, x_r, y_s$, belonging to $]-1, 1[$. To avoid convergence problem due to the Green function and its derivative when discrete points x_m is equal to x_p or x_r and when y_n is equal to y_q or y_s ; the series of discrete points x_m, y_n use a different basis than the series of x_p, y_q and x_r, y_s . It is why sum on m, n are truncated to N_g while sum on p, q and r, s are truncated to $N_g - 1$.

Radiation impedances result

In figures 19 and 20 the mean square velocity and the radiated sound power of a steel plate is presented for several values of the number of Gauss interpolation points. It is seen that the effect of varying N_g is more important on the radiated power than on the mean square velocity because the sound radiation of the system is directly related to the radiation impedance matrix.

The characteristics of the plate, of the excitation and of the fluid used in this simulation are described in the table 1 (section 8.1).

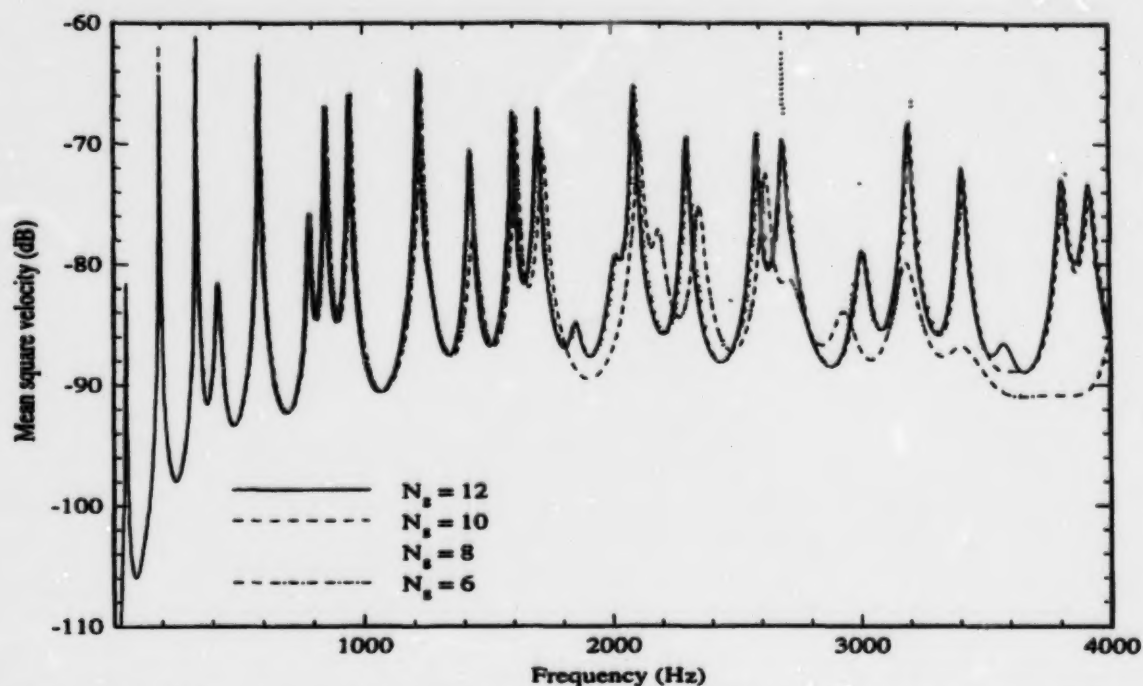


Figure 19. Mean square velocity of a steel plate for various values of the number of Gauss interpolation points N_g .

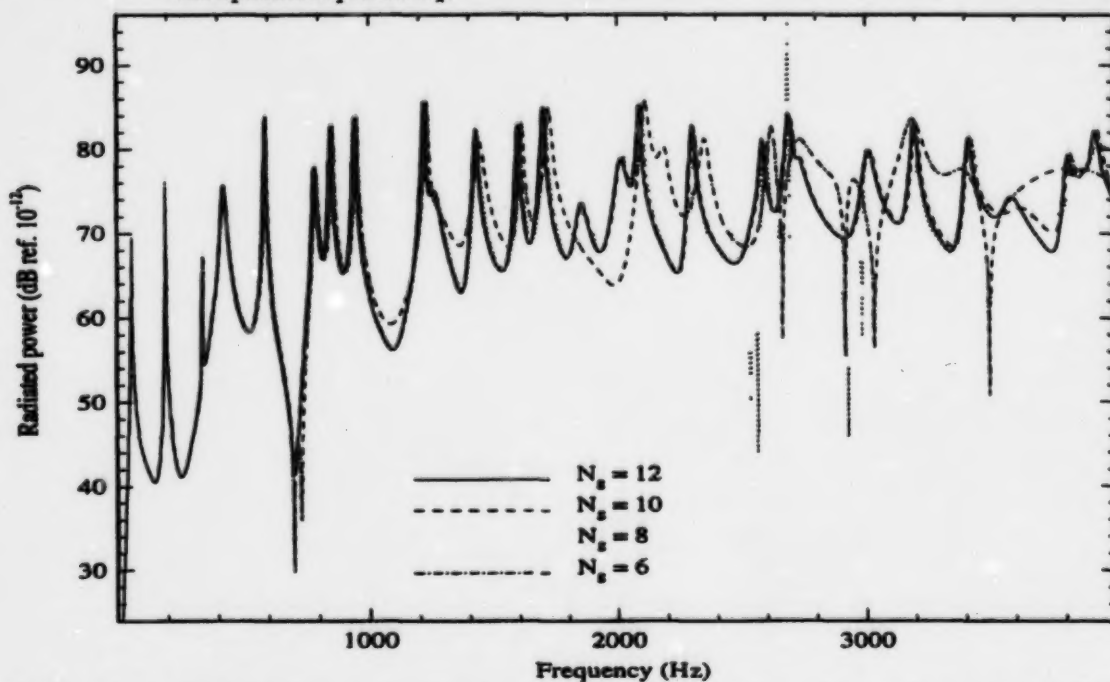


Figure 20. Radiated sound power of a steel plate for various values of the number of Gauss interpolation points N_g .

8 Frequency interpolation of the radiation impedances

The calculation of the radiation impedance matrix with the numerical interpolation (see section 8.2) can be computationally heavy if many Gauss interpolation points are used. In this section, the possibility to perform frequency interpolation on the numerical calculation of the radiation impedance matrix is investigated in order to decrease the computation time. Figures 21 to 28 present several modal radiation impedance coefficients as a function of the frequency. Two types of impedance matrix coefficients can be defined : the direct terms (Z_{mm}) and the cross coupling terms (Z_{mpq}). Figures 21 to 25 present some direct terms and figure 26 to 28 present some cross coupling terms. For the direct terms the imaginary part is larger than the real part in low frequencies, but this tendency changes in high frequencies. It means that the added mass effect (related to the imaginary part of the radiation impedance) is dominant in low frequencies and the radiated damping (related to the real part of the radiation impedance) is dominant in high frequencies. The cross coupling terms oscillate around zero in all cases. From these results it is seen that the radiation impedance coefficients have smooth, slow variations with frequency, so that the frequency step associated with the calculation of the radiation impedance may be larger than the frequency step associated with the calculation of the vibration/acoustic response.

In the code WinVIBRO2, a linear interpolation procedure for the radiation impedance terms is possible. The radiation matrix is calculated at the frequency f_0 and at $f_0 + \delta f$. The value of the matrix between f_0 and $f_0 + \delta f$ is calculated using the following relation :

$$Z_{mpq}(f) = \left(\frac{Z_{mpq}(f_0 + \delta f) - Z_{mpq}(f_0)}{\delta f} \right) (f - f_0) + Z_{mpq}(f_0) \quad (5)$$

The characteristics of the plate, of the excitation and of the fluid used for this test are described at the table 1 (section 8.1).

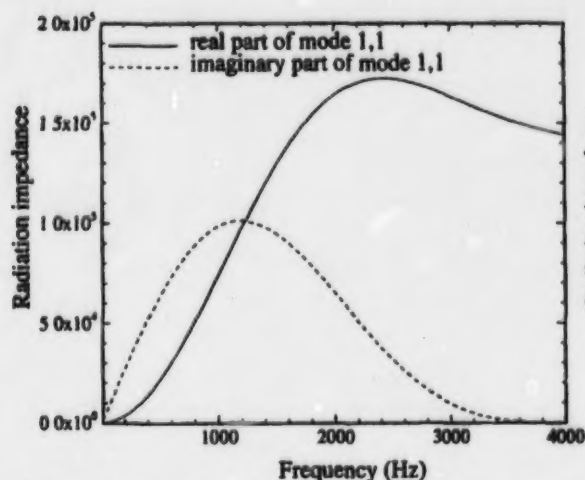


Figure 21, direct radiation impedance term for the mode 1,1.

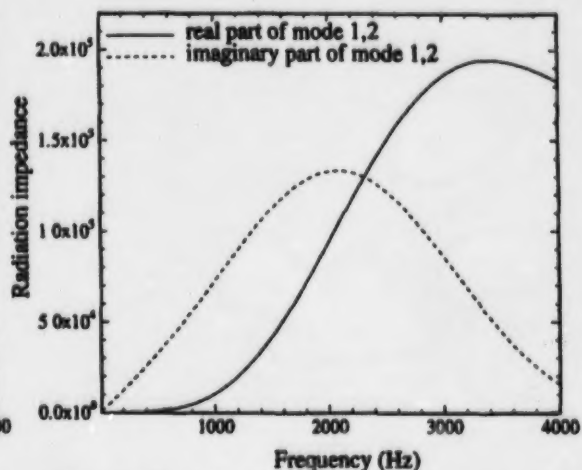


Figure 22, direct radiation impedance term for the mode 1,2.

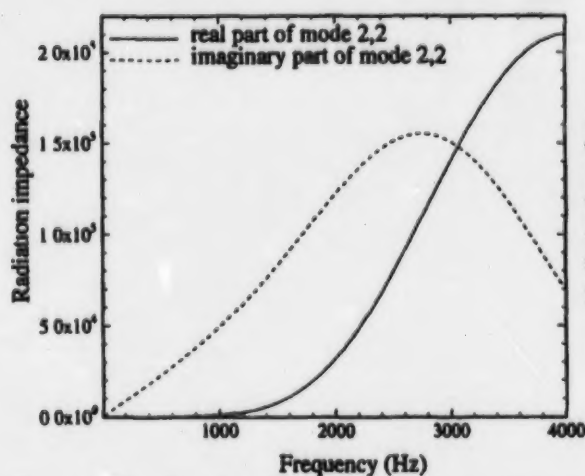


Figure 23, direct radiation impedance term for the mode 2,2.

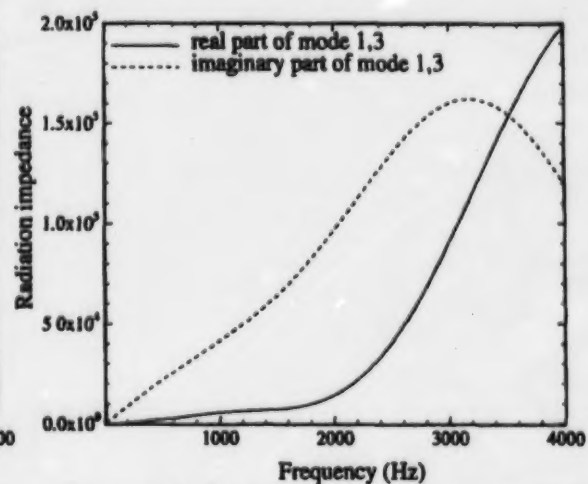


Figure 24, direct radiation impedance term for the mode 1,3.

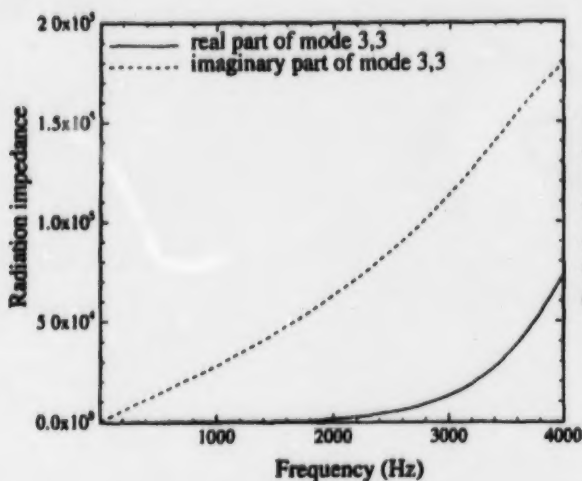


Figure 25, direct radiation impedance term for the mode 3,3.

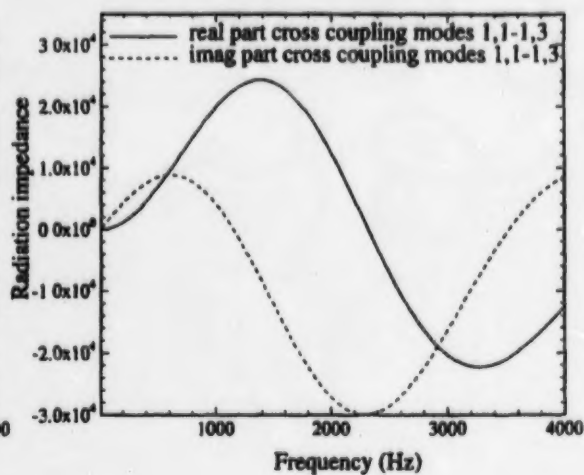


Figure 26, cross coupling term of the radiation impedance for the modes 1,1 - 1,3.

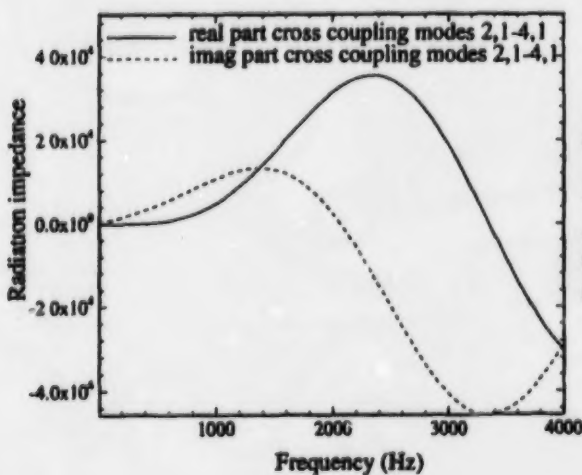


Figure 27, cross coupling term of the radiation impedance for the modes 2,1 - 4,1.

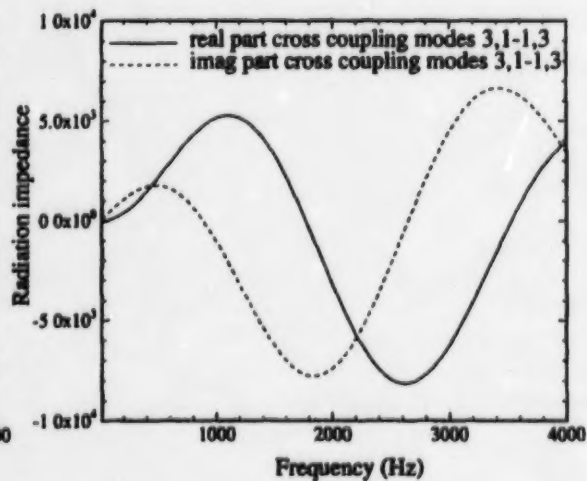


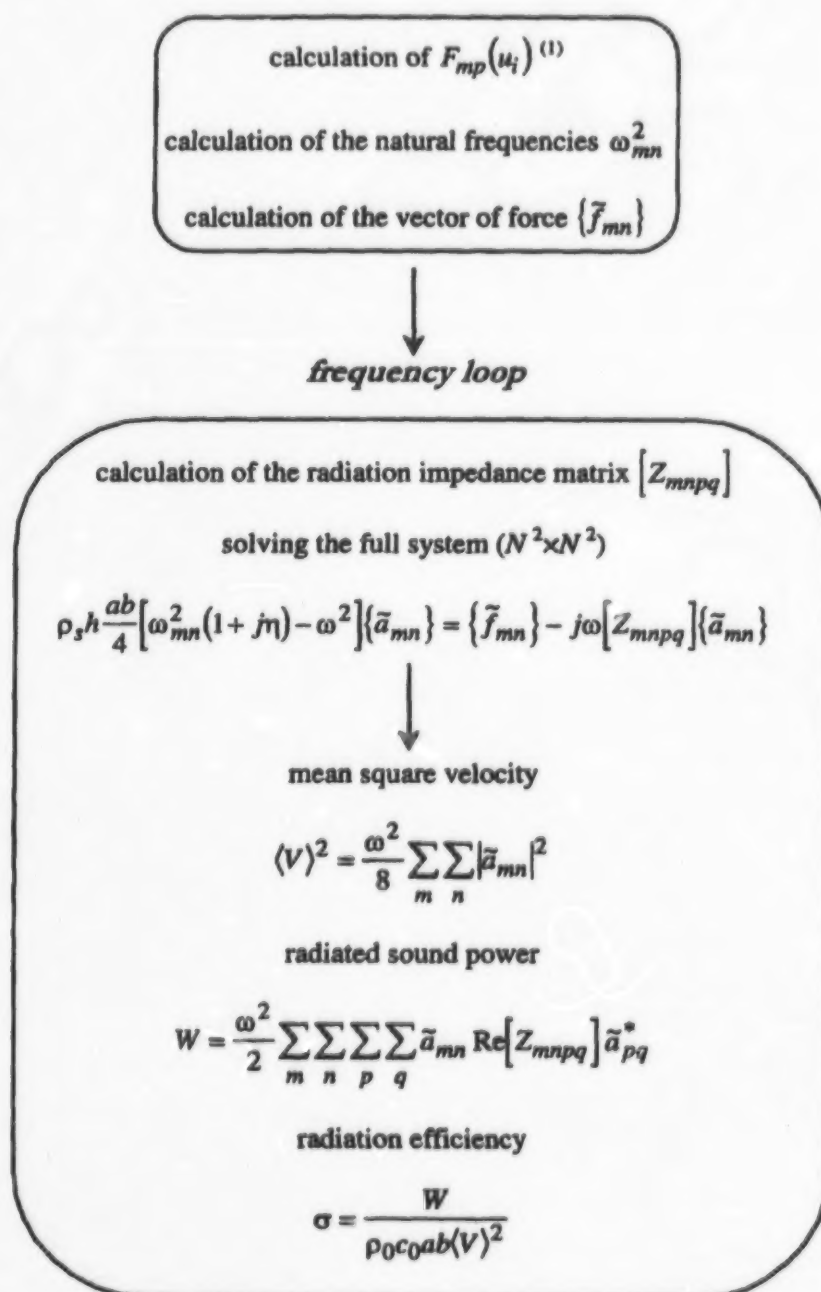
Figure 28, cross coupling term of the radiation impedance for the modes 3,1 - 1,3.

9 Algorithms

In the seven following pages, algorithms of the seven methods implemented in the program are presented :

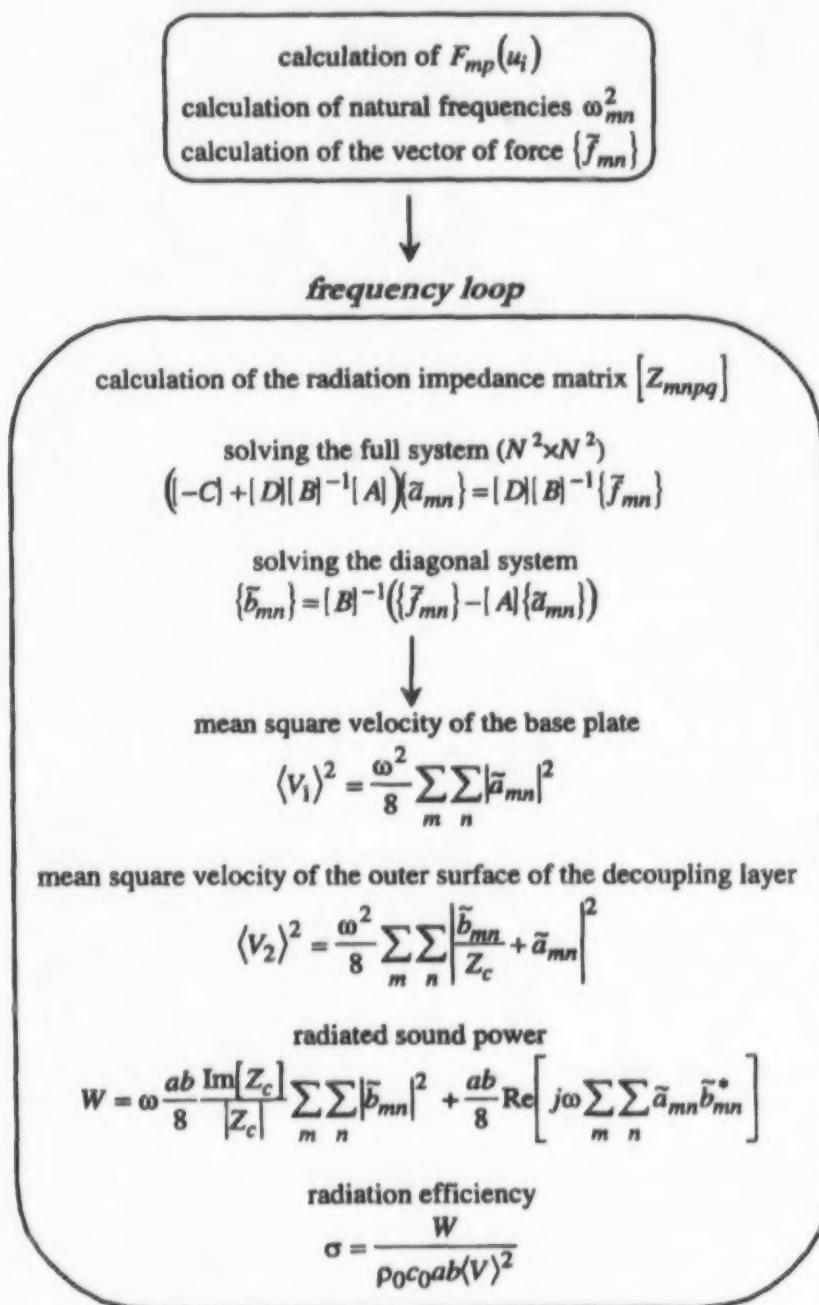
1. Simply supported base plate
2. Base plate covered by a decoupling layer (locally reacting model)
3. Base plate covered by a decoupling layer (complete 3D model)
4. Base plate covered by a decoupling layer (simplified 3D model with only compressional wave)
5. Sandwich plate (elastic-viscoelastic-elastic)
6. Sandwich plate covered by a decoupling layer (the decoupling layer is modeled with the locally reacting model)
7. Partial coverage of plate with a constrained damping treatment

9.1 Base plate alone



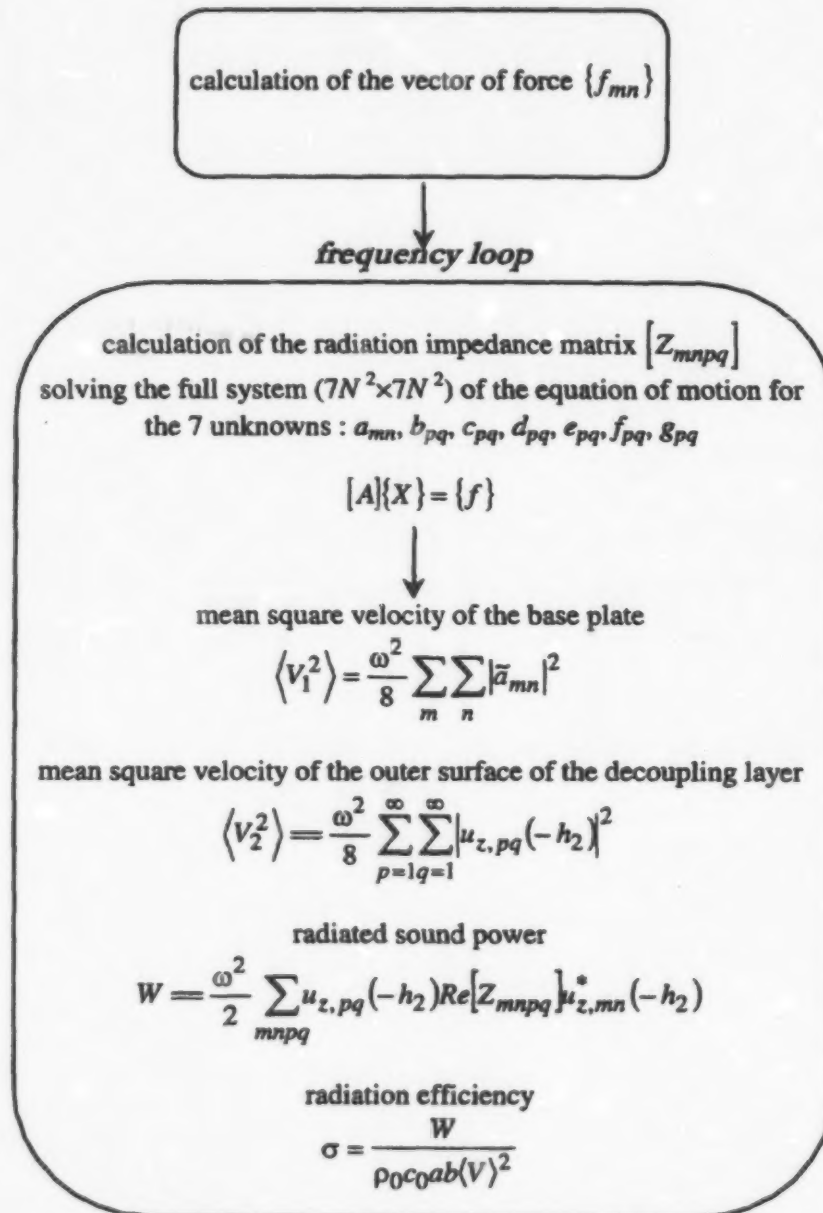
⁽¹⁾ The integral $F_{mp}(u_i)$ is used to build the radiation impedance matrix (defined in appendix 2 of the DREA report CR/96/427).

9.2 Base plate + decoupling layer



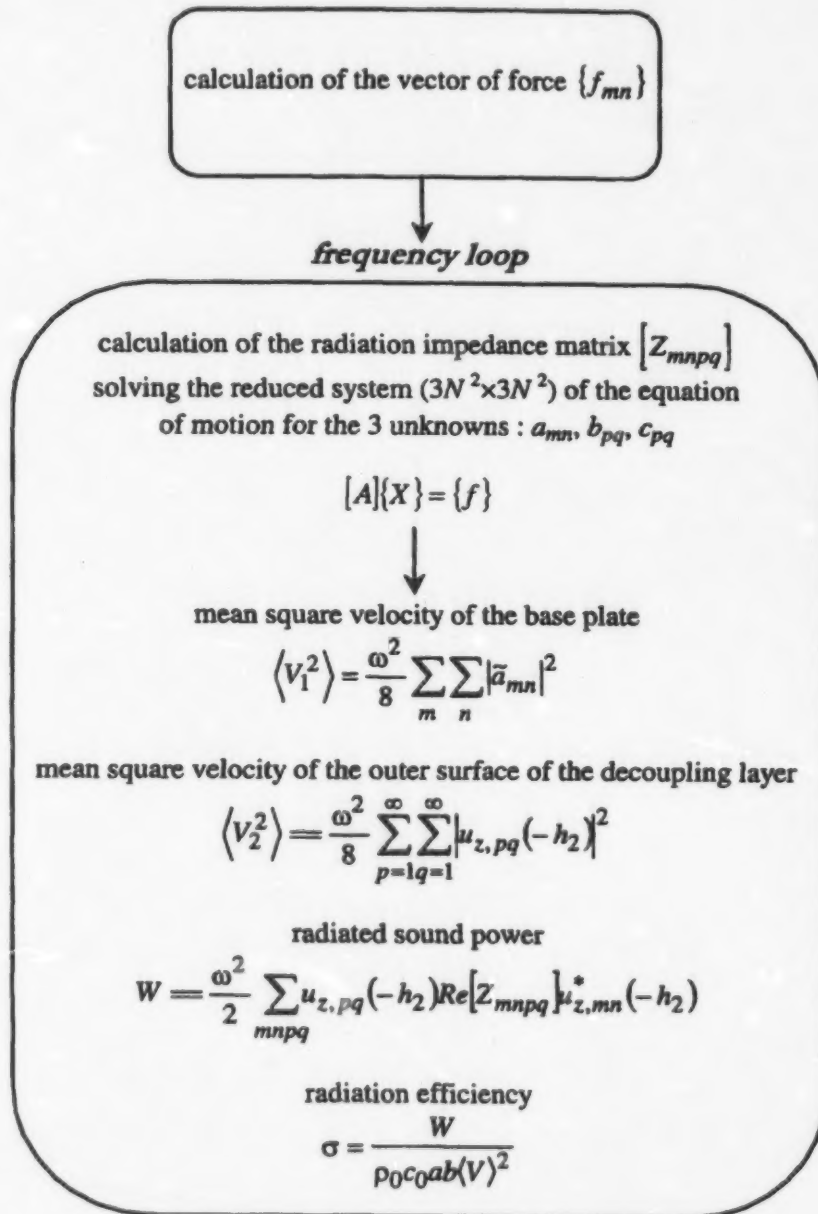
matrices $[A]$, $[B]$, $[C]$, $[D]$ are defined in the chapter 3 of the DREA report CR/96/427.

9.3 Base plate + decoupling layer (3D model)



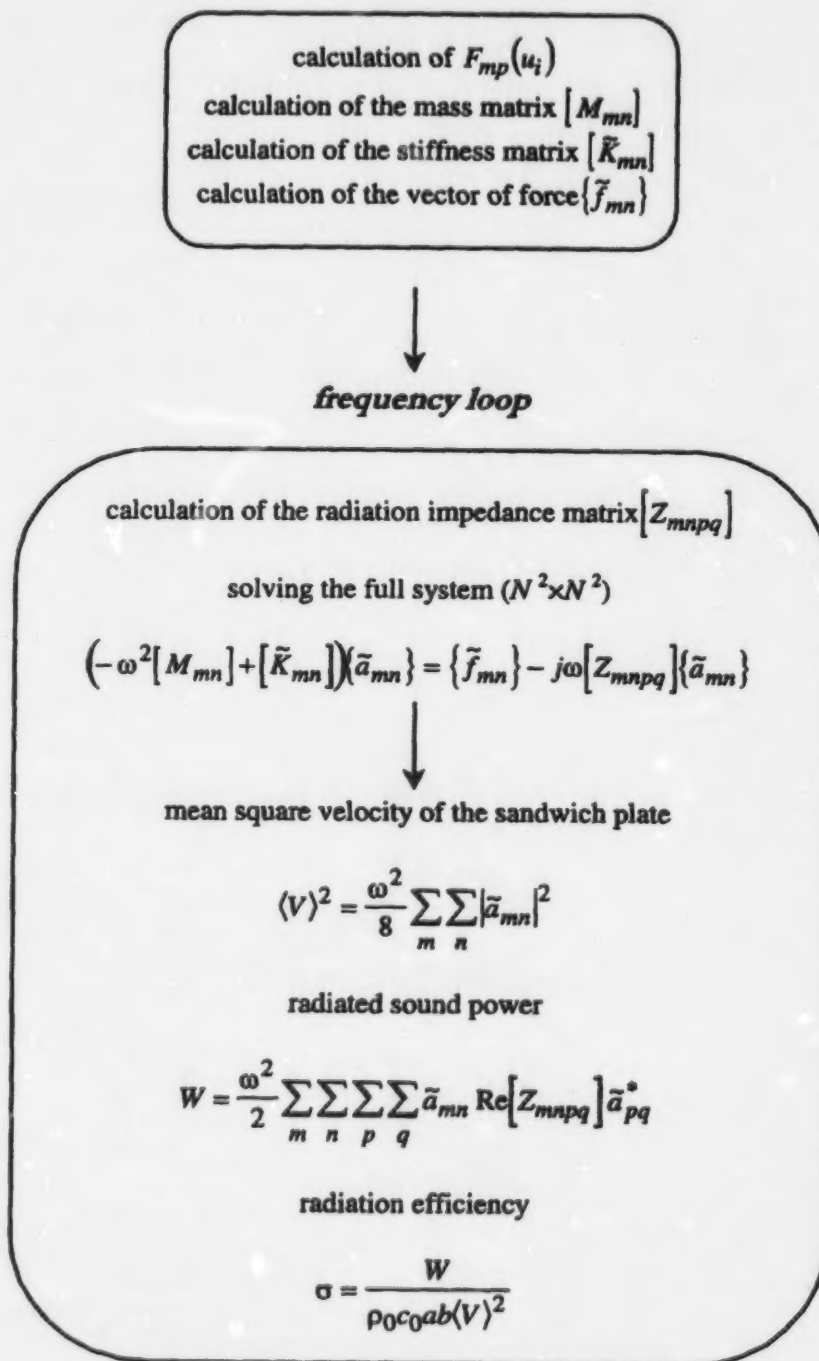
see chapter 2 of "Computational evaluation of decoupling and damping materials – Phase III".

9.4 Base plate + decoupling layer (simplified 3D model with only compressional wave)

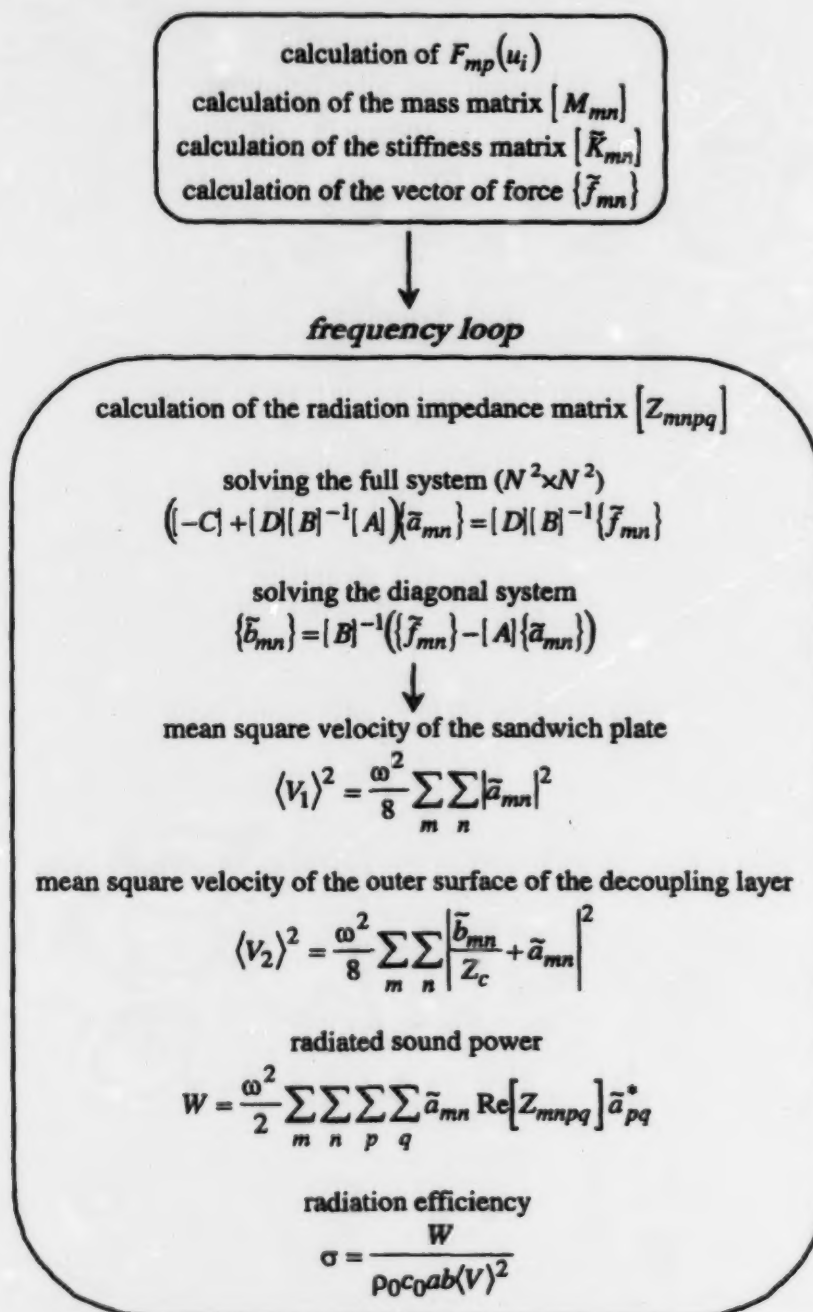


see chapter 2 of "Computational evaluation of decoupling and damping materials – Phase III".

9.5 Sandwich plate (variational approach)

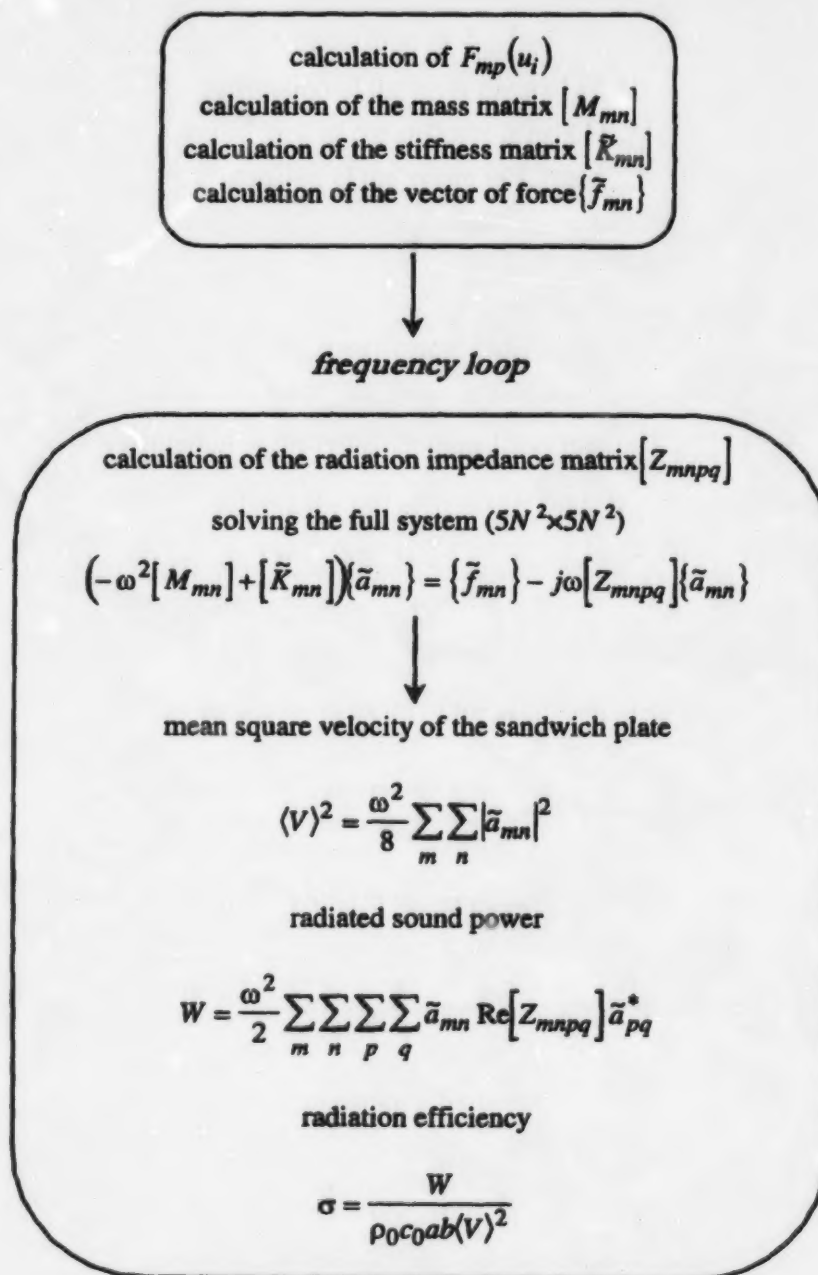


9.6 Sandwich plate + decoupling layer



In that case $[A] = (-\omega^2[M_{mn}] + [\tilde{K}_{mn}])$, matrices $[B]$, $[C]$, $[D]$ are unchanged from the case 10.2.

9.7 Partial coverage of damping material (variational approach)



In that case the dimension of the matrices is ($5N^2 \times 5N^2$) instead of ($N^2 \times N^2$) for the simplified model for sandwich plate (see chapter 4 of "Computational evaluation of decoupling and damping materials - Phase III").

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This document is a guide for using the Windows 95/98 version of the computer code WinVIBRO2, an implementation of theoretical models presented in the DREA Reports "Computational Evaluation of Decoupling and Damping Materials, Phase I and III". This code allows the vibroacoustic response of a baffled, rectangular plate immersed in a heavy fluid on one side to be calculated, either with or without a noise reduction coating. Seven numerical algorithms are implemented in the code : (1) the case of a base plate alone, the case of a base plate covered by a decoupling coating (3 models are available : (2) locally reacting model, (3) 3D model and (4) simplified 3D model), (5) the case of a sandwich plate, (6) the case of a sandwich plate covered by a decoupling coating and (7) the case of a base plate partially covered by a constrained viscoelastic treatment. The input parameters required for the code are described, the method to use the code is presented as well as the vibroacoustic indicators calculated by WinVIBRO2. Algorithms used for the main types of numerical methods available in the program are also listed.

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